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ABSTRACT

A series of studies investigated whether infants can detect cues in ongoing speech that could help them delineate those segments that correspond to grammatical units like phrases and words. The methodology of the study involved asking whether infants show a preference between speech samples in which pauses have been inserted coincident with the boundaries of the unit in question versus those in which pauses have been inserted at a location internal to the unit. Findings, overall, indicate that by the age of 4 and one-half months infants show a sensitivity to prosodic cues in speech that are correlated with speech segments that span clausal units in language, and this sensitivity obtains whether the language is English or whether it is an unfamiliar language, Polish. By about 6 months, this sensitivity has narrowed to English. But 6-month-olds do not appear to show a sensitivity to cues that are correlated with speech segments that correspond to finer linguistic units. Not until 9 months of age can infants detect cues that can mark segments corresponding to the clause-internal strucure formed by the major phrase constituents. Not until 11 months of age is there apparent sensitivity to cues that correlate with the packaging of syllable strings into unfamiliar words. Possible interpretations of the findings are discussed. (RH)

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Developmental Trends in Infants' Sensitivity to Prosodic Cues Correlated with Linguistic Units

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Developmental Trends in Infants' Sensitivity to Prosodic Cues

Correlated with Linguistic Units

Attention to cues that mark units of speech corresponding to full clauses is a potentially significant step for the language learner. Sensitivity to these cues could let the learner know at least roughly how to carve up the speech stream into those units of sound that carry coherent information about the rules by which sentences convey meaning. Without such sensitivity, a learner exposed to strings longer than a single clause could be led hopelessly off-track in the search for the underlying rule system of the language. Many theories of language acquisition simply start with the assumption that the sounds of single sentences serve as the inputs that the child is trying to decipher (Maratsos & Chalkley, 1980; Morgan, 1986; Wexler & Culicover, 1980). Our findings should provide some solace to those who have made this assumption, since children hear many multi-sentence inputs. In fact, our findings may also suggest a solution to one of the problems that has received explicit notice -- namely that the learner could be misled if incomplete sentences or sentence fragments are considered proper data (Chomsky, 1965). In principle, at least, attention to the same constellation of cues that signal segmentation into well-formed clausal units could also permit incomplete or ill-formed segments to be differently regarded or disregarded.

So the evidence that Jusczyk just presented concerning infants' sensitivity to prosodic cues in speech segments that correspond to full clauses could certainly help the acquisition system get going and help it stay on track. Is it possible that the prosodic structure of the input provides help of an even richer nature? Are infants also sensitive to some cues in the speech stream that could help them discover organization within clauses? In a series of studies that I describe now, we have asked whether infants can detect cues in ongoing speech that could help them delineate those segments that correspond to grammatical units like phrases and words. Let me mention that we had a few junior collaborators in virtually all the work that we are describing today, but Amanda Woodward deserves special mention in this talk since she not only participated in the phrase studies but initiated the studies on words in her undergraduate thesis at Swarthmore

College.

The methodology used in these studies is entirely parallel in conception and in most details to that used in the clause studies just described by Jusczyk. It relies on asking whether infants show a preference between speech samples in which pauses have been inserted coincident with the boundaries of the unit in question versus those in which pauses have been inserted at a location internal to the unit.

Since I can save some time in the description of the methodology --relying on your memory for Jusczyk's presentation--, let me take a few moments here to let you hear what our contrasting samples sounded like. First is an example of a matched pair of samples used in studies described by Jusczyk, samples of child-directed speech interrupted at clause boundaries in the first instance or within the clause in the second instance. I'll show you a transcription of these samples at the same time -- with slashes marking the insertion of artificial pauses. (Play them.) Now let me play a parallel pair where the comparison has to do with the new question of sensitivity to cues related to segmentation into finer units. In the Coincident version of the sample you'll hear, the inserted pauses are placed at the boundaries of the major phrasal constituents within the clause: the boundaries between subject-noun phrases and predicate-verb phrases. In the Noncoincident versions of these samples, the inserted pauses interrupt the phrases--the subject noun phrases in some samples and the predicate verb phrases in the others. It's the subject noun phrase that gets interrupted in the particular sample you'll be hearing. (Play Storybook samples in Coincident and Noncoincident versions).

Having just heard and seen this last pair of samples, you won't be surprised to learn that--in contrast to the first pair I played, the original speech from which the phrase samples were derived consisted of speech that was not spontaneous. It was generated by a woman reading a prepared storybook to a child. We asked her to read the book as naturally as possible and gave her plenty of opportunity to familiarize herself with it--but, of course, her reading is likely to differ in some ways from spontaneous speech (Remez, Rubin, & Ball, 1985). Still, there were several benefits of having prepared samples for experimental purposes--which will become

evident as I talk. In fact, all the major phrase-related results that have been obtained with these storybook samples have also been found using samples of spontaneous child-directed speech. This is useful to know because the samples were also quite different in other ways. In contrast to the storybook speech, where we purposefully included only declarative sentences and sentences with long subject noun phrases, the spontaneous samples (typical of normal child-directed speech to 2 year olds) contained many questions and often used a single pronoun as the subject noun phrase. For a Coincident version of such a sample, a typical sentence like: "Are you playing with the cat?" would be interrupted before the main verb, between "you" and "playing"; a Noncoincident version would be interrupted right after the main verb, between "playing" and "with".

So, are prelinguistic infants sensitive to cues in the speech stream that could mark its segmentation into spans corresponding to major phrasal units? For 9 month olds, the answer clearly appears to be "yes". We have now obtained a reliable preference from 9 month olds in 5 different comparisons, 2 with the storybook samples, 3 with the spontaneous samples. The results from one of each kind are given in the next transparency. The preferences are quite robust. In the Storybook study, 21 of the 24 infants showed a preference in the direction of the Coincident versions. And all 12 different samples pairs patterned that way. Moreover, the preference for the Coincident versions seemed to be equally large regardless of whether the Noncoincident version was interrupted within the subject-noun phrase or within the predicate-verb phrase. In the second study, using spontaneous samples, 13 of 16 nine month old infants tended to prefer the Coincident versions, and, again, all sample differences were in that direction. Consistently, then, in 9 month olds, the tell-tale preference obtains at the level of phrasal constituents, just as it did at the level of full clauses.

The storybook data that I have just presented actually came from a larger study in which we also asked whether, in parallel to what we found at the level of clauses, child-directed speech puts infants at a special advantage in detecting cues relevant to the phrasal units. With the prepared storybook samples, we could make a direct comparison between adult-directed and

child-directed versions of speech that had exactly the same content. To get our adult-directed samples, we called back to the lab the same woman who had generated the child-directed samples, and asked her to read the same stories as naturally as possible to an adult. The next transparency shows the full set of data from the study. Our analyses revealed that, as was true at the level of clauses, preferences were stronger within the child-directed than within the adult-directed speech, as if child-directed speech is a better source of segment-correlated cues. Moreover, matching the content of the child-directed and adult-directed samples, as we did in this study, allows us to pinpoint prosodic cues as a major information source for the infants.

The next transparency again contains some information you've seen before--the 9 month olds' phrase results from the 2 studies of child-directed speech, but now two relevant comparisons involving 6 month olds are added. And the pattern for the 6 month olds appears to be markedly different. In neither of these cases nor in 2 additional studies of 6 month olds have we been able to obtain any reliable evidence of a preference within our phrase stimuli.

So there seems to be a potentially interesting developmental trend here--and one that apparently complements the developmental difference just reported by Jusczyk. Recall that with regard to clause-correlated cues, sensitivity seemed to narrow at least temporarily to English, the native language, by about 6 months. What we find now is that between 6 and 9 months of age, a new sensitivity to English prosody appears to come in--a sensitivity to cues that correspond to the marking of major phrasal segments.

Let me enrich the developmental picture still more with some preliminary results concerning sensitivity to word-marking cues. In these studies, by analogy to our studies at the clause and the phrase level, the issue is whether the infant is sensitive to cues in the speech stream that might distinguish the boundaries of words from within-word locations. More particularly, can the infant detect cues that differentiate between adjacent syllables that correspond to different words and adjacent syllables that belong to the same word? The samples we used came from the child-directed storybook speech, which, conveniently, contained enough multisyllabic words for us to ask the question. Let me play you a pair of samples--first a

Coincident version (where the pause is inserted between words), next a Noncoicident version (where the pause is inserted between syllables of the same word). In this particular case, the pause is inserted at a word boundary inside a minor phrase in the Coincident version. In other samples, the Coincident word-boundary interruptions were also at minor phrase boundaries -- e.g., before a prepositional phrase--but we have not picked up any evidence that this makes a difference. (Play the word samples and show the transcriptions.)

The next transparency contains the results from studies of three different age groups on these kinds of samples--4 1/2 month olds, 9 month olds, and and 11 month olds. Again, there appears to be a developmental effect. Only the 11 month olds show any evidence of detecting the cues that relate to word boundaries, as shown by a reliable preference. Neither the 9 month olds nor the 4 1/2 month olds show differential orientation times. The preference of the 11 month olds has been replicated in a separate study.

Overall, then, the developmental picture across our various studies looks like this: By 4 1/2 months (the youngest age group we can test in our procedure), infants show a sensitivity to prosodic cues in speech that are correlated with speech segments that span clausal units in language, and this sensitivity obtains whether the language is English or whether it is an unfamiliar language, Polish. By about 6 months, this sensitivity has narrowed to English (and we're uncertain as of yet as to when it comes back). But 6 month olds do not appear to show a sensitivity to cues that are correlated with speech segments that correspond to finer linguistic units. Not until 9 months of age can infants detect cues that can mark segments corresponding to the clause-internal structure formed by the major phrase constituents. And not until 11 months of age is there apparent sensitivity to cues that correlate with the packaging of syllable strings into unfamiliar words.

What should we make of these developmental trends? Well, I suppose that depends on how willing we are to throw caution to the winds, for there's quite a lot that we don't know yet. Importantly, we are only in the beginning stages of trying to do some acoustic analyses of our actual speech samples in order to try to find out what particular kinds of information are

differentially available to our infants at the various unit boundaries and within-unit locations. At present, all we can do is rely on the analyses performed by other investigators on other speech samples in order to make some guesses about what the cues might be that infants are responding (or not responding) to (e.g., Bernstein Ratner, 1985; Cruttenden, 1986; Cooper & Paccia-Cooper, 1980; Morgan, 1986). We do know that in the case of clause-correlated sensitivity, some of the cues are prosodic --since we get the preference in infants even when the samples are filtered to leave only prosodic information. Prosodic cues are strongly implicated for the phrase-related sensitivity also; that is certainly the best guess as to what distinguishes our adult-directed and child-directed samples that are matched entirely for content. In the case of sensitivity at the word level, the prosodic cues could be implicated as well (e.g., Nakatani & Dukes, 1977; Nakatani & Schaffer, 1978), although we have no direct evidence that they account for our results. (Possibly, knowledge of particular words or of how prosodic cues tend to correlate with particular words could be responsible for the sensitivities infants demonstrate in our word studies.)

One possible interpretation of our developmental trends starts with the reasonable assertion that from clauses to phrases to words, prosody marks less well (i.e., with fewer or less reliable or less pronounced or less highly correlated cues) the related segments of speech. Perhaps what we are seeing in infants across the first year of life is simply an increasing sensitivity to the same set of prosodic cues. So, if more cues and more reliable cues are present to distinguish unit boundaries from unit locations, as in the clause stimuli, even very young infants show a sensitivity to the difference between them. If fewer and less reliable cues distinguish the locations, only the older infants show the discrimination.

Another possibility, perhaps more likely, is that the particular cues and/or packaging of cues into correlated bundles differ at least partially in kind for speech segments corresponding to the different linguistic units. Major phrase boundaries internal to a clause may be marked in a different way (not just less well) than clause boundaries. If this notion of different kind of marking is correct, and if different languages also mark major phrase units (and word units)

with language-specific kinds or combinations of prosodic cues, as has been suggested, then it makes good sense that language-specific experience would be necessary before these cues are attended to. And two possibilities exist as to how their significance for the infant could arise. First, on the assumption that correlated prosodic cues serve as markers, exposure to the frequent correlation of these cues with one another over time may be enough to prompt perceptual learning (e.g., Gibson (1969). However, a second possibility is that the infant is prompted to learn about these prosodic marking cues from evidence of the status of the units that comes from sources largely independent of prosody. An example of what I have in mind in the second case is that local repetitions of the same major phrasal constituent, typical of child-directed speech (Newport, 1977), could serve as independent evidence of the psychological coherence of the spoken phrase unit (e.g., Morgan, 1986), prodding the child to search for prosodic cues that tend to be correlated with it. (The same thing could occur, of course, at the level of the word.) Having been originally directed to the prosodic cues from extra-prosodic sources, the child could come to rely on these prosodic cues to recover the units when extra-prosodic information is lacking.

On this last view, one might take the evidence that sensitivity to prosodic markers for phrases comes in only with linguistic experience as suggesting that it awaits a critical discovery outside of prosodic structure. One could argue as well (and I think more plausibly) that the causal arrow would run in both directions: prosodic information and other sources of information mutually reinforcing one another's significance in carving the input into the right units (see Morgan, 1986).

In all this speculation as to what to make of the developmental trends, I have moved quite a distance from the methodology used in our experimental studies. In the last section of this talk, I want to return the focus to the methodology and to the question of what inferences the data collected within our methodology warrant. To briefly review, then, our experimental paradigm allows us to measure infant preferences, from which we infer discrimination ability. And the discrimination that is critical is that between two kinds of samples of speech--neither of them

naturally occurring, both of them constructed by inserting pauses in several locations within a sample. But, we argue, by consistingly inserting the pauses in one kind of location in one set of samples and a different kind of location in a matched set of samples, discrimination between them may tell us something about how natural speech is perceived by the infant. Now, in our methodology, the infants can tell us if they can discriminate between:

(a) pauses + whatever stimulus characteristics are naturally available at the unit boundaries, and

(b) pauses + whatever stimulus characteristics are naturally available at locations within the unit.

Clearly they cannot do this unless they are taking into account some characteristics that were already available in the speech before we tampered with it (assuming we have been careful, as we have, to avoid creating transients when we insert our pauses). So our results indicate that the infants can pick up this naturally available information up in some context. But, in seeking to extrapolate from our results to natural speech processing, two important questions arise.

One is whether the pause cue itself, the cue we have added, is itself critically bound up in an integral fashion in the effective psychological stimulus for the infant. If it is, then what the infants are telling us is that they know what kinds of other stimulus characteristics tend to co-occur frequently with pauses and which don't. This in itself could be significant in processing natural speech , since it might serve as a basis for differentiating pauses that serve--say--pragmatic functions and pauses that mark what Cruttenden (1986) calls "intonation groups", which correspond frequently to major grammatical units.

However, we think that an interpretation of our findings in terms of how infants specifically perceive pause-correlated cues is an unlikely explanation of some of our results and hence not the most parsimonious explanation of all of our results. In the Coincident versions of our spontaneous phrase stimuli and the Coincident versions of our word stimuli, the pauses were inserted at points in the speech stream which should be unlikely locations for pauses -- for example, in the phrase stimuli, after an auxiliary and a subject pronoun that start a

question--such as after "Are you" in "Are you trying to get that?", or in the middle of a prepositional phrase in some of our word stimuli. Accordingly, it seems implausible that the naturally available cues in these speech samples at these points were ones that usually occur along with pauses. Hence, there is some reason to believe that we got our preferences for the Coincident versions, when we did, because the original stimulus characteristics and the added pause provided redundant sources of information about how the speech stream should be segmented--and not simply because the infants thought that the added pause and the original stimulus characteristics constituted a good, single, natural-sounding integral cue.

But this brings up another important issue. Suppose our infants were showing only an avoidance, and no preference in the positive sense at all. That is, suppose it's an aversion to the Noncoincident samples that accounts for all the effects we have gotten. What the infants know, if you will, and all they know is that the conjunctions of pauses with the kinds of cues that ordinarily occur in the middle of units are particularly unlikely. Now, this is knowing something surely, but it could only be helpful in normal speech processing to sort out false starts or pragmatic uses of pauses. The significance of our results for understanding normal language acquisition would be enhanced if one believed that at least part of the differential orientation to Coincident and Noncoincident samples is due to an attraction to the Coincident versions.

Let me end by pointing to a pattern that seems to be emerging across our studies because it suggests some positive preference for the Coincident stimuli when differential orientation occurs. The pattern obtains when presentation of Coincident versus Noncoincident samples interacts with some other variable--be it a stimulus variable (e.g., child-directed vs. adult-directed speech) or a subject variable (age). The notable finding is that when the difference between orientation times to Coincident and Noncoincident samples is larger at one level of the second variable than at the other, it is the longer orientation times to the Coincident samples (rather than shorter orientation times to the Noncoincident samples), which seems to be carrying the effect. For example, consider again the impact of child-directed versus

adult-directed speech on 9-month-olds' orientations to the storybook phrase samples. Notice it is the longer orientation times to the Coincident Child-directed samples that is the data point that stands out. Similarly, reconsider the interaction with age shown in the two comparisons with phrase stimuli. For both Storybook samples and Spontaneous samples, the interaction is due to the fact that the 9 month olds orient longer than the 6 month olds to the Coincident samples (rather than less long than the 6 month olds to the Noncoincident samples). Finally, the developmental pattern in the word studies is only a bit less clean. When the preference comes in at 11 months, it is because, relative to the pattern at 9 months, there is increased orientation to the Coincident samples. Only the less compelling comparison of the 11 month olds all the way back to the 4 1/2 month olds suggests any differential influence of the Noncoincident samples across age. Accordingly, although it is difficult to get a logically secure handle on this issue, there are these converging suggestions in our data that the differential orientation patterns that signal our critical effects emerge because Coincident samples are positively preferred. We believe that this strengthens our argument that infants are showing a kind of sensitivity within our methodology that has implications for the understanding of natural speech processing, and as Hirsh-Pasek will now address--for the understanding of how language acquisition can proceed.

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Table 1

Sample of a Stimulus Pair for the English Clause Studies.

Slashes indicate inserted pauses.

Coincident Version:

So, she was so tired / and she saw this house in the woods, / and she thought, / "Oh well, I'll just go inside for a little bit / and sit, / and maybe they can tell me how to get home."

Noncoincident Version:

. . .the flowers. So, she was / so tired and she saw this house in / the woods and she / thought, "Oh well, I'll just go inside for a little / bit and / sit, and maybe they can tell me how. . ."

Table 2

Sample of a Stimulus Pair for the Storybook Phrase Studies.

Slashes indicate inserted pauses.

Coincident Version:

Everybody talks on the telephone. Your Mom and Dad / can call anyone, anywhere. Many people with jobs / need a telephone answering machine to take messages for them during the day. A good answering machine / will collect your messages. A very polite person / will say, "hello," to the person calling on the phone. A nice phone operator / will help you place a call.

Noncoincident Version:

Everybody talks on the telephone. Your Mom / and Dad can call anyone, anywhere. Many people / with jobs need a telephone answering machine to take messages for them during the day. A good / answering machine will collect your messages. A very / polite person will say, "hello," to the person calling on the phone. A nice phone / operator will help you place a call.

Table 3

Mean Length Orientation Times of 9 Month Olds to Phrase Stimuli Composed from Child-Directed Speech

	Coincident	Noncoincident
Storybook Sample	9.20 s.	6.55 s.
Spontaneous Samples	8.83 s.	7.09 s.

Table 4

Mean Length Orientation Times of 9 Month Olds to Storybook Phrase Stimuli

	Coincident	Noncoincident
Child-directed Samples	9.20 s.	6.55 s.
Adult-directed Samples	7.69 s.	6.61 s.

Table 5

Mean Length Orientation Times to Child-Directed Phrase Stimuli

	Coincident	Noncoincident
Storybook Samples		
9 month olds	9.20 s.	6.55 s.
6 month olds	6.80 s.	6.34 s.
Spontaneous Samples		
9 month olds	8.83 s.	7.09 s.
6 month olds	6.37 s.	6.22 s.

Table 6

Sample of a Stimulus Pair for the Word Studies.
Slashes indicate inserted pauses.

Coincident Version:

Some very / big animals live at the zoo. These very / big animals are elephants. (Oh boy!) The smaller baby / elephant is walking with her mother. Both / the mother and the / baby have long trunks instead of noses. The baby / elephant / and her mother are looking for food. Plants, grain, and / peanuts are good / food for elephants.

Noncoincident Version:

Some very big ani/mals live at the zoo. These very big animals are ele/phants. (Oh boy!) The smaller baby ele/phant is walking with her mother. Both the mo/ther and the baby have long trunks in/stead of noses. The baby ele/phant and her mo/ther are looking for food. Plants, grain, and pea/nuts are good food for ele/phants.

Table 7

Mean Length Orientation Times to Word Stimuli

4 1/2 month olds	9.24 s.	9.27 s.
9 month olds	7.81 s.	7.89 s.
11 month olds	9.79 s.	7.00 s.